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Left Versus Bi-Atrial Intraoperative Saline-Irrigated Radiofrequency Modified Maze Procedure for Atrial Fibrillation

Mustafa Guden,[1] Belhhan Akpinar,[1] Baris Caynak,[1] Cavlan Turkoglu,[2] Zeki Ozyedek,[2] Ilhan Sanisoglu,[1] Ertan Sagbas,[1] Saide Aytekin[2] and Seher Deniz Oztekin[3]

[1]Department of Cardiovascular Surgery, [2]Department of Cardiology and [3]School of Nursing, Kadir Has University, Florence Nightingale Hospital, Istanbul-Turkey

Abstract. ***Background:*** **This study was conducted to evaluate the effectiveness of the saline-irrigated radiofrequency modified maze operation for the treatment of chronic atrial fibrillation (AF) and compare the results of the left and bi-atrial procedures.**

Material and method: **During a period of two years, 105 patients with chronic AF having concomitant cardiac surgery underwent the procedure.**

Patients underwent either a bi-atrial ($n = 48$) or left atrial ($n = 57$) maze procedure. The first twenty patients underwent a bi-atrial maze procedure regardless of the pathology. In the following patients we adopted the bi-atrial approach in patients with a history of atrial flutter and where the right atrium has to be opened. Otherwise the procedure is restricted to the left atrial side. Mean age was 52 ± 11 years in bi-atrial group and 54 ± 9 years in left atrial group.

Results: **Three patients died early postoperatively (2.9%). There were 4 revisions for bleeding (3.8%). Two patients in bi-atrial group received a permanent pacemaker (4.1%). Patients in both groups were free of AF at the end of the procedure. (Bi-atrial group: sinus: 79.2%, pacemaker: 20.8%), (Left atrial group: sinus: 82.5%, pacemaker: 17.5%) ($p > 0.05$). During the last follow-up, sinus rhythm was maintained in 79.6% of cases in bi-atrial group, while this rate was 75.6% in left atrial group ($p > 0.05$).**

Conclusion: **Saline irrigated radiofrequency modified maze procedure was performed safely and efficiently. Both the left and bi-atrial procedures were successful in terms of restoring sinus rhythm. Our current policy is to adopt the bi-atrial approach in patients with a history of atrial flutter and where the right atrium has to be opened. Otherwise the procedure is restricted to the left atrial side.**

Key Words. **saline-irrigated radiofrequency, modified maze, atrial fibrillation**

Introduction

Atrial fibrillation (AF) remains one of the most prevalent arrhythmias and has negative impacts on survival [1]. Radiofrequency (RF) is an energy source that has been used commonly during percutaneous ablation techniques for different rhythm disturbances. Its use during the surgical treatment of AF is a relatively new, but fastly adopted modality. This fast adoption is mostly due to the relative surgeon friendliness of this energy system in comparison to the original surgical cut and sew technique. Various groups have reported high one-year success rates using RF energy [2,3]. However, many points remain uncertain; such as the definition of success rates, patient selection, type of energy used and the ablation pattern.

Some groups who have adopted an ablation pattern involving only the left atrium have reported favorable results, while others insist on the routine use of a bi-atrial approach [2,4]. Some recent studies have failed to show any difference in sinus rhythm restoration rate in patients undergoing a left or bi-atrial maze procedure.

In this study, we aimed to compare patients undergoing a left only or a bi-atrial ablation procedure with saline-irrigated RF system (Cardioblate, Medtronic Inc., Minneapolis, MN) in terms of sinus rhythm restoration, complications and long-term outcome.

Material and Methods

The Ethical Committee of the hospital approved the study. An informed consent was obtained from each patient. Data were prospectively collected from patients undergoing concurrent open heart surgery with AF to receive the procedure. The technique used will be addressed as the "Saline-Irrigated Radiofrequency Modified Maze" (SIRFMM) throughout the text. Patients with at least 6 months of persistent AF have been included in the study. During 2 years, 105 patients who met these criteria underwent

Address correspondence to: Belhhan Akpinar, M.D., Florence Nightingale Hospital, Abide'i Hürriyet Cad. No. 290, 80220 Şişli-Istanbul-Turkey. E-mail: belh@turk.net

Table 1. *Demographic and clinical characteristics*

	Bi-Atrial Group $n = 48$	Left Atrial Group $n = 57$
Age	52 ± 11	54 ± 9
Gender (female/male)	34/14	34/23
Rheumatic mitral valve	51%	54%
Mean LVEF	$52 \pm 10\%$	$53 \pm 10\%$
NYHA functional class	2.9 ± 0.8	2.7 ± 0.3
Preoperative atrial fibrillation	100%	100%
Coronary artery disease	7 (14.6%)	8 (14%)

LVEF: Left ventricular ejection fraction.

the SIRFMM procedure. The bi-atrial and left-atrial groups were comparable in gender, age, mitral valve pathology and left ventricular function (Table 1).

The RF ablaion system and the surgical technique have been previously described in detail [5].

Forty-three patients underwent combined SIRFMM, and mitral valve procedure through a port-access approach.

Left-sided SIRFMM

After cardioplegic arrest, left atrial incision was performed through the interatrial groove. Both cavae were encircled with tapes for total CPB to have a dry field during ablation. The left atrial appendage (LAA) was either amputated and sutured afterwards or a circumferential radiofrequency lesion was created around its base and the orifice was oversewn from inside the atrium. After the LAA was excised, an ablation line from the LAA to the left superior pulmonary vein was created. In addition to the incision in the interatrial groove, isolation of the right pulmonary veins was completed by a circular ablation line. The left pulmonary veins were encircled and a connecting line was performed between both islands of pulmonary veins as near to the left atrial roof as possible to avoid injury to esophagus. An ablation line from the left pulmonary veins to the posterior mitral annulus was then performed with caution not to injure the circumflex coronary artery. The left index finger of the surgeon or administration of retrograde cardioplegia enabled the surgeon to locate the circumflex artery and avoid any injury during the procedure. In some cases, following the placement of a surgical instrument in the coronary sinus from the right side to push up against the left atrial wall to locate where the coronary sinus ended on the left side, an ablation line from the middle of the mitral valve ablation line down towards the base of the atria was performed to prevent the re-entry pathways moving between the atria via the coronary sinus (Figure 1). Following left-sided Maze procedure, LAA amputation site was sutured with horizontal mattress suture technique using pericardial strip for reinforcement. Concomitant procedures were performed only after completing the left-sided ablation.

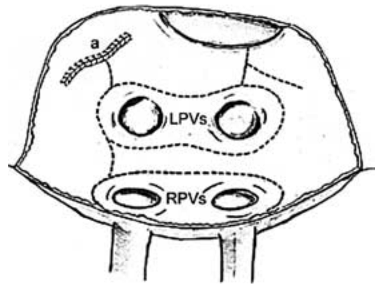

Fig. 1. *Left atrial operation. The dots indicate radiofrequency ablation lines performed in the left atrium. See text for details. a: excised and sutured left atrial appendage; LPVs: left pulmonary veins; RPVs: right pulmonary veins.*

The left-sided maze procedure added 9–12 minutes to the original operation.

Right-sided SIRFMM

The right-sided procedure was performed during rewarming on partial bypass after the removal of cross clamp. After snaring both caval cannulae, the right atrial appendage (RAA) was excised and an incision (4 cm) was made anteriorly from the amputated RAA towards the inferior vena cavae. A second posterior longitudinal and lateral incision was performed at the dorsolateral aspect of the right atrium and extended to the AV groove reaching the interatrial septum. Between the superior and inferior caval cannulation sites, the endocardial surface was ablated (Figure 2). Additional RF ablation lines were performed from the excised RAA to the anterior tricuspid leaflet and from the caudal end of the posterior longitudinal incision at the atrioventricular groove to the posterior portion of the annulus of the tricuspid valve. The right-sided procedure was completed with

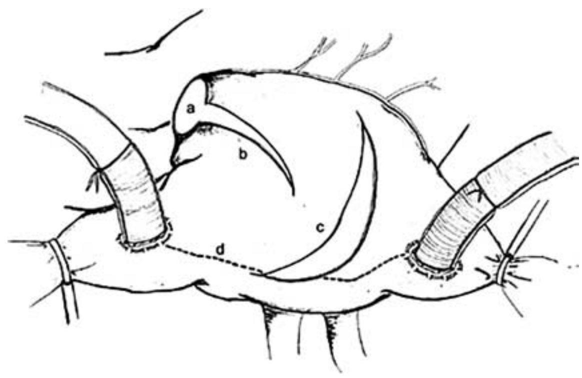

Fig. 2. *a: The right atrial appendage is excised. b: A 4 cm vertical incision towards the vena cava is performed. c: A second posterior-longitudinal incision is made in the right atrium. d: An ablation line is created within the right atrium between the superior and inferior caval cannulation sites.*

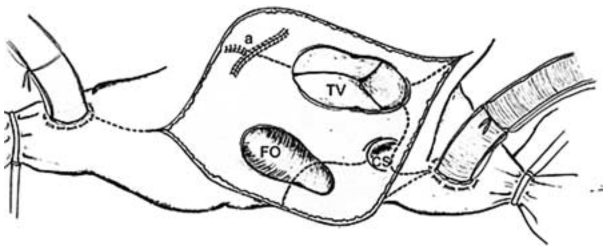

Fig. 3. *The dots indicate the radiofrequency ablation lines performed in the right atrium. Please refer to the text for a detailed explanation. a: the excised right atrial appendage is sutured; CS: coronary sinus; FO: fossa ovalis; TV: tricuspid valve.*

an ablation line performed on the right side of the interatrial septum starting from the middle of the right atriotomy across the fossa ovalis up to the caudal aspect of the coronary sinus, followed by an ablation line performed from this point to the inferior vena cava and up to the posterior annulus of the tricuspid valve (Figure 3). Following the completion of ablation the right atrial incisions were closed using 4–0 prolene. The right-sided Maze added 6–9 minutes to the original procedure.

Decision to perform left or Bi-atrial procedure

A bi-atrial maze procedure was applied in cases where the right atrium had to be opened for a tricuspid valve inspection, an atrial septal defect or if the patient had a former atrial flutter. Patients with atrial flutter underwent a similar bi-atrial procedure. Otherwise, the procedure was limited to the left side. In this way, we had two subgroups of patients.

Bi-atrial group. Patients who underwent both left and right-sided Maze procedure (48 patients).

Left atrial group. Patients who underwent left-sided Maze procedure (57 patients).

Patients in both groups underwent 24-hour Holter recordings. Twenty patients from each group were evaluated by transthoracic echocardiography (TTE) for atrial transport function during the last follow-up. Transmitral and transtricuspid flow velocities were measured with pulsed Doppler echocardiography. Peak velocities of the early (E wave) and of the late filling wave (A Wave) were measured. A peak A wave velocity of 10 cm/s was arbitrarily considered as the cut-off for an effective atrial contraction. The follow-up for the whole group ranged from 2 to 24 months (mean: 10.9 ± 5.58 months).

Statistical analysis

The two groups compared in this study were not homogeneous.

The statistical analysis was performed using the Prisma V. 3 Package Program. Fisher's exact test was used with regard to the patient population in groups. McNemar test was used to evaluate the change of a variable within time and the Unpaired t and Chi-square test test were used for comparison of different variables between two groups. $p < 0.05$ was considered significant.

Results

Table 2 shows the concomitant surgical procedures. Three patients died during hospitalization (2.9%). None of the deaths could be attributed to the ablation procedure. Two patients died due to multiorgan failure triggered by a pulmonary infection and 1 patient died due to renal failure. During follow-up 2 patients in the bi-atrial group (4%) and one patient in the left atrial group (1.7%) died. The death of the two patients was accepted as a sudden cardiac death, though the death of the patient in the left atrial group was unexplained (Table 3).

Bi-atrial group. Freedom from AF was 100% intraoperatively (sinus: 79.2%, temporary pacemaker: 20.8%). Three patients in this group needed reoperation for bleeding which was associated with the LAA amputation site in 2 cases. Two patients in the bi-atrial group required permanent pacemaker implantation one month after the surgery due to third degree of atria-ventricular block (4.1%). Figure 4 shows freedom from permanent pace-maker implantation during follow-up.

Left atrial group. Freedom from AF was 100% intraoperatively (sinus: 82.5%, temporary pacemaker: 17.5%). One patient in this group had to be reopened urgently in the intensive care unit six hours after the operation for sudden massive bleeding which was due to the partial disruption of the LAA suture line.

Table 2. *Concomitant surgical procedures*

Procedures	Bi-Atrial Group ($N = 48$)	Left Atrial Group ($N = 57$)
MVR	7 (14.6%)	31 (54.3%)
MVP	3 (6.2%)	12 (21%)
MVR + TP	8 (16.6%)	0
MVP + TP	10 (20.8%)	0
MVP + ASD	3 (6.2%)	0
MVR + AVR	3 (6.2%)	2 (3.5%)
MVP + AVR	4 (8.3%)	4 (7%)
CABG	2 (4.16%)	2 (3.5%)
CABG + MVP	3 (6.2%)	3 (5.2%)
AVR + MVR + TP	3 (6.2%)	0
AVR + CABG	2 (4.16%)	3 (5.2%)
Reoperation	4 (8.3%)	4 (7%)

ASD: atrial septal defect; AVR: aortic valve replacement; CABG: coronary artery bypass grafting; MVP: mitral valve plasty; MVR: mitral valve replacement; TP: tricuspid valve plasty.

Table 3. Complications and outcome

	Bi-Atrial Group ($N = 48$)	Left Atrial Group ($N = 57$)	Both Groups ($N = 105$)
Reoperation for bleeding	3 (6.2%)	1 (1.7%)	4 (3.8%)
MORTALITY (30 days)	2 (4.1%)	1 (1.7%)	3 (2.9%)
MORTALITY (LATE)	2(4.1%)	1(1.7%)	3 (2.9%)
Cardiac	2	0	2 (1.9%)
Non-cardiac	0	1	1 (0.9%)
Permanent pace maker	2 (4.1%)	0	2 (1.9%)
Thromboembolic event	0	0	0
Improvement in NYHA Class	2.9 ± 0.8 ↓ 1.4 ± 0.5	2.7 ± 0.3 ↓ 1.6 ± 0.3	

Table 4. The rhythm status of patients

Perioperative	Bi-Atrial Group ($N = 48$)	Left Atrial Group ($N = 57$)	Last Follow-Up 10.9 ± 5.58 (2–24) Months	Bi-Atrial Group ($N = 44$)	Left Atrial Group ($N = 55$)
Sinus rhythm	38 (79.2%)	47 (82.5%)	Sinus rhythm	35 (79.5%)	42 (76.4%)
Temporary pacemaker	10 (20.8%)	10 (17.5%)	Atrial fibrillation	9 (20.5%)	13 (23.6%)

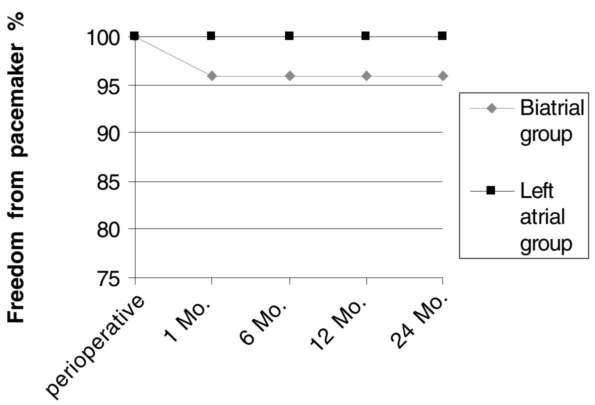

Fig. 4. *Freedom from permanent pacemaker implantation during follow-up.*

The LAA amputation site was repaired and patient recovered uneventfully.

Table 4 shows the rhythm status of patients; intraoperatively, and during follow-up. Figure 5 shows freedom from AF in both groups during follow-up. Holter ECG recordings revealed more episodes of atrial arrhythmias, AF and atrial flutter (AFL) in the left atrial group ($p < 0.05$) (Table 5).

During follow-up 2 patients in the left atrial group developed atrial flutter and were managed by catheter ablation. Atrial transport function was evaluated during the last follow-up using TTE with doppler analysis of mitral and tricuspid flows. There was no difference in left and right atrial transport function between two groups ($p > 0.05$) (Table 6). New York Heart Association (NYHA) functional class improved significantly in both groups. No thromboembolic events were observed in either group during the follow-up period.

Table 5. 24-Hour holter ECG results

% of Patients	Bi-Atrial Group	Left Atrial Group	P Value
Atrial arrhythmias	30.2	51.4	$P < 0.05$
Episodes of atrial fibrillation	8.2	20.8	$P < 0.05$
Episodes of atrial flutter	0	4	$P < 0.05$

Table 6. The evaluation of atrial transport function

	Bi-Atrial Group	Left Atrial Group
Left atrial transport	70%	75%
Right atrial transport	75%	80%

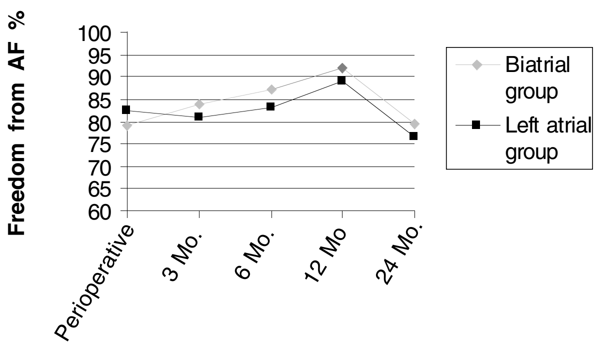

Fig. 5. *Freedom from AF in both groups during 24 months follow-up.*

Postoperative considerations

After 3 reoperations for bleeding from the LAA amputation site, the authors prefer not to amputate the LAA anymore. Instead, a circumferential radiofrequency lesion around the base of the LAA within the left atrium was performed followed by oversewing of the orifice. The advantage of excluding the LAA anatomically is the likelihood of a lower stroke incidence

Temporary epicardial pacing wires (atrial and ventricular) were implanted at the end of the operation as a precaution against temporary A-V block. Anticoagulation management protocol was the same as that applied for routine open heart surgery. Patients receiving mechanical valves continued to receive coumadin. For patients who remained in sinus rhythm, the INR was kept around 2 for aortic valves and between 2.5–3 for mitral valves. Patients in sinus rhythm with echocardiographicly documented atrial transport function do not receive coumadin, if they do not have a mechanical valve.

As early postoperative arrhythmias may be caused by mechanisms other than chronic AF, patients were given 200 mg/day amiodarone on a routine basis for a period of three months. We do not favor early cardioversion for patients in postoperative AF, and reserve this for patients who are still in AF after three months. Two patients in Group B who were in AF three months postoperatively were cardioverted, but one patient remained in AF despite cardioversion. This patient continued to receive amiodarone.

Discussion

AF is a common arrhythmia affecting 0.4% of the general population and up to 10% of the persons over the age of 65. More importantly, 60% of patients admitted for mitral valve surgery and up to 5% of patients undergoing coronary revascularization have chronic AF [6]. When AF is not treated during surgery, the rate of spontaneous sinus rhythm recovery is in the range of 15 to 20% [7,8]. Even with the extensive use of antiarrythmic medicatons and aggressive electrical cardioversion, the reported rates of late sinus rhythm maintenance remain below 25% [9]. In the field of catheter treatment, radiofrequency energy has been used for the treatment of focal AF and other supraventricular tachycardias [10]. Surgical ablation to isolate the pulmonary veins is currently superior to percutaneous ablation with respect to length of procedure time, ease of creating continuous lesion lines, possibility of resection of the atrial appendage, and prevention of pulmonary vein stenosis.

The maze III procedure described by Dr Cox remains the gold standard for surgical treatment of AF [11]. The Maze III procedure is the only treatment of AF that can achieve the three major goals; restoration of sinus rhythm, A-V synchronization and atrial transport function. However, it is an extensive and time-consuming technique, which precludes the widespread application of this operation. In an effort to reduce the technical concerns with the procedure. A variety of other sources such as cryo, microwave, bipolar cautery and RF have been used to create lesions similar to those used in the original "cut and sew technique". Sie and Khargi, were among the first to use the irrigated RF device for the surgical treatment of AF [2,3]. These success rates were followed by other groups [5]. Sie reported a freedom from AF of 98 and 86%, at one and two years respectively [12]. Sie et al. claim that the high success rate in their series is due to routine biatrial Maze procedure and believe that performing only left sided procedure can compromise these results.

Haissaguerre et al. and Chen et al., reported a focal source of paroxysmal AF originating from the pulmonary veins [13,14]. Sueda et al. hypothesized that AF might originate from pulmonary veins and they only perform simple pulmonary vein orifice isolation for the treatment of chronic AF associated with mitral valve disease [4].

Although various concepts involving reentry and ectopic foci have been proposed to explain the mechanism underlying AF, the real mechanism underlying AF associated with mitral valve disease remains unknown [15,16]. The aim of the Maze procedure is to seperate all possible areas for macroreentry and to restore atrial contractility. Greater understanding of the mechanism of success for the surgical ablation may advance the development and success of other approaches. It is also not very clear if the results of ablation are due to linear lessions to prevent reentrant circuits or to the elimination of triggers.

A recent review of literature shows that one year sinus rhythm restoration varies between 62–98% among series using RF energy [17–20]. These differences can be attributed to variations in patient selection, ablation patterns, and technique. The choice of lesion pattern during the ablation procedure differs among groups, thus having an implement over the success of the procedure [20]. A recent study has shown that a lesion pattern comprising of electrically isolating the pulmonary veins, left atrial appendage and left atrial connecting lesions was 100% effective in terminating AF in an animal model in comparison to other models which consist of pulmonary vein isolation alone [21]. This is similar to our ablation procedure. On the other hand, simple pulmonary vein isolation seems to have a lower sinus rhythm restoration rate suggesting that simplifying the procedure comes at a cost of lower sinus rhythm restoration rates [4,19,22]. The authors believe that simple pulmonary vein isolation may not be sufficient in all cases and the Maze concept should be adopted to address all possible mechanisims of AF.

Recently Yamauchi et al. reported that with the aid of epicardial mapping, sustained reentrant movement or repetative firing from foci located in the right atrium was never observed and the left atrium played an important role as the electrical driving chamber for AF [23].

In our study, although the patients in biatrial group suffered fewer episodes of atrial arrhythmias and atrial flutter in the early postoperative period, there was no difference in sinus rhythm restoration between patients who had undergone biatrial or left sided procedure [5]. Similarly Deneke et al. and Williams et al. reported that left atrial Maze procedure was as effective as the bi-atrial procedure [24,25].

An advantage of the left sided limited procedure is that it obviates the need for some incisions. Usui et al., reported postoperative incidences of atrial flutter reaching 10% after left sided simple maze procedure [26]. If a patient develops atrial flutter after the operation, this can be managed by catheter ablation. Two patients in our series were treated with catheter ablation. Catheter based techniques will increase the costs of this strategy and may not be available in all centers.

The right-sided portion of the bi-atrial procedure, especially ablation around the isthmus area, increases the risk of AV block. This complication occurred in two of our patients (4.1%).

An important aim of restoring sinus rhythm is to produce atrial contraction and to restore atrioventricular electromechanical synchrony and to decrease the risk of cardiac thoromboembolism. In our study, left atrial contraction was restored in 75% of patients in SR after left atrial approach and in 70% of patients after bi-atrial approach. Several minimally invasive surgical approaches have recently been applied to treat mitral valve disease with or without AF, in an effort to minimize surgical trauma and improve cosmetic results [27]. After the initial success with surgical treatment of AF, efforts were aimed towards performing these procedures through less invasive approaches [28]. Mohr and associates, have shown the feasibility of creating ablation lines using RF energy during minimally invasive valve procedures in a large series. They reported a six months and one year sinus rhythm restoration rate of 78% and 69% respectively in a group of 133 patients. This was a subset of 234 patients operated during a three years period showing the feasibility of RF ablation through a port access approach [22].

In our series of patients, 43 patients underwent combined SIRFMM and mitral valve procedure through a port-access approach [29].

In conclusion, the SIRFMM procedure was safe and effective in restoring sinus rhythm. This study failed to show a difference in sinus rhythm restoration rate between patients undergoing a left or bi-atrial Maze procedure. Based on the published and personal experience, our current policy is to adopt the bi-atrial approach in patients with a history of atrial flutter and when the right atrium has to be opened otherwise the procedure is restricted to the left side. Greater understanding of the mechanisms for the success of surgical ablation will advance the development of the surgical treatment of AF.

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